# Progress in understanding
# Arcs and Gradient Limits in Warm Cavities

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**Our primary effort has been to understand arcs and gradient limits.**

This is a confused field, (many more variables than data points in any expt.)

Many mechanisms, many disciplines, fast processes, inconsistencies, etc.

Little agreement on basic mechanisms after 110 years.

Many seem to have essentially given up trying to understand mechanisms.

Anders book essentially ignores arc internals.

Burkhard Juttner reviews highlight inconsistencies.

Tokamak / Fusion groups have little active effort.

There seems to be a real "breakdown" of the scientific method.

**Our approach combines experiment and modeling:**

Long experience with plasma wall tokamak community

- The APEX tokamak at Argonne, saw unipolar arcs in vacuum chamber.
- Over the years, ANL had an effort with plasma/wall community.
- Carbon limiters and divertors reduced interest for the last 20 years.
- Held Unipolar Arc workshop last year.

Our X ray data measured the environment at breakdown sites.

- A unique, direct way to measure pre-breakdown conditions.
- Defines properties of enhancements/emitters/breakdown sites.

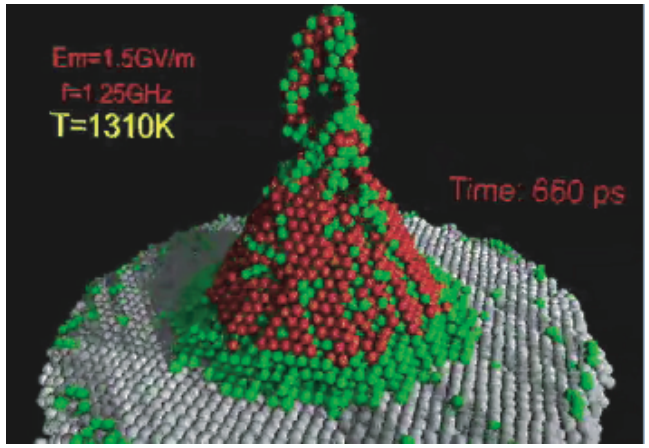
We do a variety of modeling and experiments.

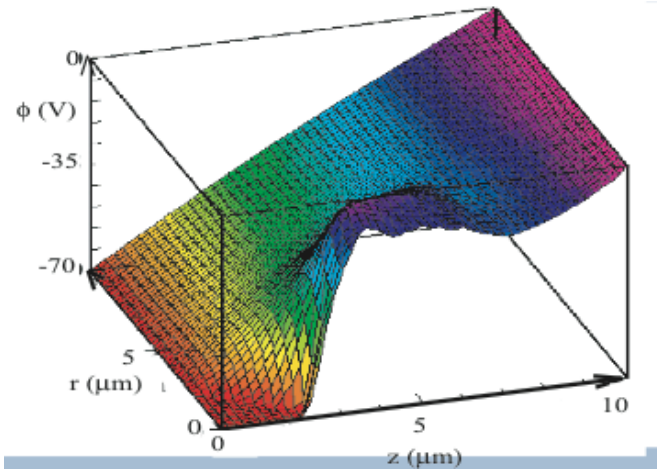
- Rf data from the FNAL MTA and Lab G.
- ALD data from the third floor of 362.
- Collaborate with TECH-X for PIC code plasma modeling.
- Z. Insepov, MCS, does Molecular Dynamics and other modeling.

**We have developed a simple, self-consistent model based on:**

Coulomb Explosions

Unipolar arcs




Many processes are involved, however:

We argue the plasma heats the wall, not the other way around.

Self-sputtering maintains the plasma.

There are two limiting arc forms: Killer⇔parasitic arcs.

Plasma pressure and tensile stress change the surface.

Spinodal decomposition.

Particulates.

Field Enhancements are primarily small blunt corners.

The internal mechanisms of the arc are unstable.

Triggers mechanisms are hard to prove experimentally.

Ohmic, electromigration, fatigue, all => ~$E^{30}$

We believe most of the "conventional wisdom" is wrong.

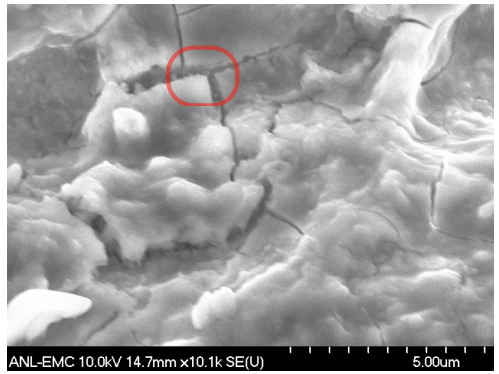
## Muon work

High rf gradients in high B fields are MAP's primary exp. problem.

MTA
- Experimental identification of parasitic / killer arcs
- Measurement of plasma emission with $\theta_{B,E}$ = 0, 90 deg

ALD experimental planning
- Designing cavity
- Designing ALD system
- Optimizing ALD procedure
  - Problems with ALD W adhesion
    - Developing techniques to measure adhesion
    - Uuniformity, conductivity, different metals
  - Want adhesion, conductivity vs. T
  - Safety for ALD in the MTA takes lots of time.
  - Design work is going slowly, we need help.

a)

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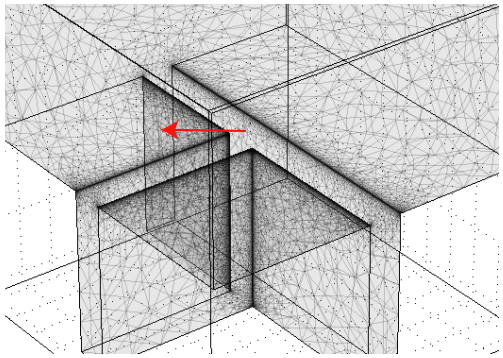

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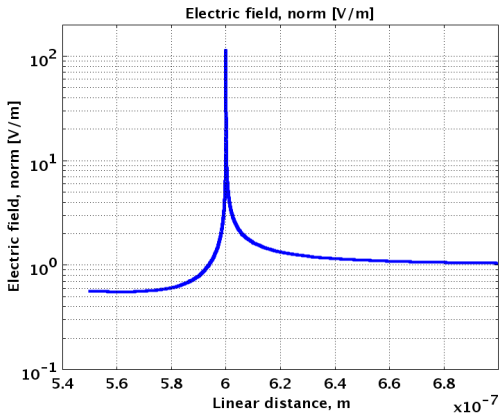

**Other Applications /**

When the number of variables exceeds the data points, you need more expts.

Coulomb explosions / Unipolar arcs seem to explain a lot.

Tokamaks

Arcs and hot spots not well understood

Stability and purity of fusion plasmas depends on this

Trying to organize a collaboration MIT/PPPL/ORNL to extend studies.

Invited talk on "Modeling Arcs" at RF in Plasmas Workshop next week.

3D B fields, pre-existent plasmas are hard numerical problems.

E beam welding

Unipolar arcs can explain pits in SRF structures

These pits can limit SRF gradients

Power grid

Need to understand basic processes to improve efficiency and stability.

HV insulation .

Coronal losses.

Fault tolerance needs to improve.

## Summary

Our effort started by measuring x ray backgrounds expected in detectors.

We now have a model self-consistent model that explains most behavior.

We are trying to continue modeling effort with plasma labs.

We are designing an ALD experiment for the FNAL MTA.